Educational Product	
Educators & Students	Grades 5–12

EB-2001-12-021-JPL

Educational Brief

CASSINI SCIENCE INVESTIGATION

Observing Outer Planets

Objective

To allow students to practice making regular observations of a natural phenomenon and record appropriate data; and to understand the effect of Earth's orbital motion on objects in the sky and the apparent motion of outer planets.

Time Required: 10–20 minutes weekly for several months

Saturn System Analogy: Deep Space Network antenna tracking of Cassini during its orbital mission at Saturn

Keywords: Constellation, Planet, Prograde, Retrograde, Retrograde Loop, Rise, Set, Star

MATERIALS

- Simple Planet Orbit Chart, Star-Rise Chart, and Simulated-Motion Chart (attached to this Educational Brief — see Student Worksheet section)
- Pencil
- Straightedge
- Clipboard (or other portable writing surface)
- Freeware and shareware planetarium programs and numerous pages on the World Wide Web can provide star charts and planet positions for instructor preparation for this activity. The planets Saturn, Jupiter, and Mars are especially suitable for this activity, though Venus (and with much more difficulty, Mercury) can also be used.

Procedure

Over the course of several months, students should make weekly (or more frequent) observations of the rise time of available planets and bright stars in the night sky. Eventually, the initially observed objects will be rising in daylight; other objects can be chosen for additional work or conclusions can be drawn based on the observation set already completed.

In addition to noting rise times, students should carefully sketch on a star chart the position of the planet(s) being observed. These positions will be connected and eventually compared to the classroom planetary motion activities described below, using the simple *Planet Orbit Chart* (see Student Worksheet section in this Educational Brief).

Some variations on the observation procedure should be mentioned here. If it is more convenient to observe setting times for planets and stars, the results will be the same, in that rise and set times occur 4 minutes earlier (for stars) each day. Observations will have to be made with a precision of about 1 second for the effect of a planet's motion on its rise/set time to be determined (and that amount will be variable over the course of the planet's period of visibility in the night sky). The Moon can be used as a surrogate planet instead, with some loss of apparent phenomena. Its daily change in rise time is on the order of tens of minutes (variable, depending on time of "moonth" and season); time-measurement precision, as for star measurements, should be 1 minute or less. Newspapers often give moon rise/set times for a fixed, nearby geographical point (that will almost certainly be different from where students will observe).

A distant horizon is not a requirement for the observations. The roof of a house, the top of a skyscraper, or the highest branch of a tree can be used as a comparison point. The selected "horizon" can be well above horizontal, as long as the observer's position and the "horizon" are fixed at the same place for each observation.

Students can plot the star's time of rise/set collected daily over a few weeks' time. The slope of the line will approximate 4 minutes per day. Careful measurements of different stars made over a few weeks during each season will show small variations from the 4 minute/day value. These variations are due to the ellipticity of Earth's orbit around the Sun.

The changing time of a star's rise or set can be illustrated in the classroom with the *Star-Rise Chart* (attached; see Student Worksheet section). Each student can pick any background star on the sheet. Starting on the right end of the diameter crossing Earth's orbit (actually, any of the radii can be used), students should draw a line from the orbit at that point to the selected star. Then the student should draw a line parallel to this original line of sight (by measurement or by geometric construction) such that the new line passes through the intersection of the next radius and the orbit circle, counterclockwise. Next, students should draw a –line from the second intersection point to the original star. They should immediately note that from the new orbital position, the angle between the star and the old line of sight changes. This change in angle is reflected in a change in the time of star-rise.

Observing and timing the passage of the Sun, as well as stars, can generate a more elaborate classroom and home set of observations. See Edberg, S. J., "Length of the Day," *Practical Uses of Math and Science*, an on-line refereed journal at *http://pumas.jpl.nasa.gov*, accepted October 30, 1997. The specific URL is: *http://pumas.jpl.nasa.gov/cgi-bin/layout.pl?examples:EX00000011-W:inv/examples/07_31_97_1.lbl*

The simplified Planet Orbit Chart is used to illustrate the motions of the planet that have been (or will be) observed in the sky. The Sun is at the center of the circle. The large circle represents Earth's orbit. An outer planet, without its orbital motion, is represented by the dot.

Starting on the right end of the diameter crossing Earth's orbit, students should draw a line from the orbit at that point through the planet to the background stars. Students should then continue drawing lines, one step at a time, moving around Earth's orbit in a counterclockwise direction (as if an observer were looking down on the solar system from high above the north pole). Each time step is approximately 22.5 days; this is not a magic number, just convenient.

Students should notice how the planet appears to slow down and then go backwards (retrograde) against the background stars, and then slow down and resume its "forward" (prograde) motion. Ask them how this result would be different if the planet itself were moving. (Answer: The extent of the backward motion (the retrograde loop) would be decreased.)

Students can even demonstrate the effect of simple planetary motion by repeating this lesson, adding a planet dot on each side of the original dot (about 1 centimeter left and right: see *Simulated-Motion Chart* attached). Draw a set of lines from the first three positions on the orbit through the right dot, a set of lines from the next three orbital positions through the middle dot, and the set of lines through the left dot.

The planets work the same way, but of course their motions are smooth and continuous. A continuous set of observations over several months will show the forward–backward–forward motion of the planet against the background stars. This prograde–retrograde–prograde motion is often manifested as a loop or Z among the background stars since the planes of Earth's orbit and other planets' orbits differ slightly.

Extension

The motions of an outer planet get much more interesting if one assumes that the outer planet orbits differently from what is observed in the solar system. Use the Simulated-Motion Chart again, but to simulate a planet in an orbit moving opposite Earth's direction (a retrograde orbit), connect Earth's position to the dots in the order opposite that described above (i.e., from left to right instead of right to left). Draw a strongly elliptical orbit for an Earth-like planet and observe the effects different portions of the orbit have on the apparent motion of the (stationary or moving) outer planet. Think in three dimensions and determine the apparent motion of a moving outer planet with an orbital plane that is steeply inclined compared to Earth's. Such motions are common among comets and some asteroids. As you can see, predicting the apparent motions of such objects can get challenging fast.

An observer on Earth with binoculars can see Jupiter's four large satellites. Their orbital minuets can be tracked over the course of one or more nights. On some nights, as few as two moons may be visible. Their order outward from Jupiter is: Io, Europa, Ganymede, Callisto. Their orbital periods range from less than two days to more than 16 days.

Observers with small telescopes can see the movements of Jupiter's moons and will also be able to see some of the dark belts and bright zones marking Jupiter's cloud tops. With small telescopes, observers can also discern a dark band across Saturn, Saturn's rings, and its largest moon, Titan. Titan is comparable in size to Jupiter's largest moon, Ganymede, but it is almost twice as far away from Earth and much more mysterious owing to its opaque atmosphere.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity:

3. Understands the composition and structure of the universe and Earth's place in it.

LEVEL 1 (GRADES K–2)

Knows basic patterns of the Sun and Moon (e.g., the Sun appears every day and the Moon appears sometimes at night and sometimes during the day; the Sun and Moon appear to move from east to west across the sky; the Moon appears to change shape over the course of a month; the Sun's position in the sky changes through the seasons).

LEVEL 2 (GRADES 3–5)

Knows that the patterns of stars in the sky stay the same, although they appear to slowly move from east to west across the sky nightly and different stars can be seen in different seasons.

Knows that planets look like stars, but over time they appear to wander among the constellations.

LEVEL 3 (GRADES 6–8)

Knows characteristics and movement patterns of the nine planets in our solar system (e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them).

10. Understands forces and motion.

LEVEL 1 (GRADES K–2)

Knows that the position of an object can be described by locating it relative to another object or the background.

LEVEL 2 (GRADES 3–5)

Knows that an object's motion can be described by tracing and measuring its position over time.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Observing Outer Planets

Procedure

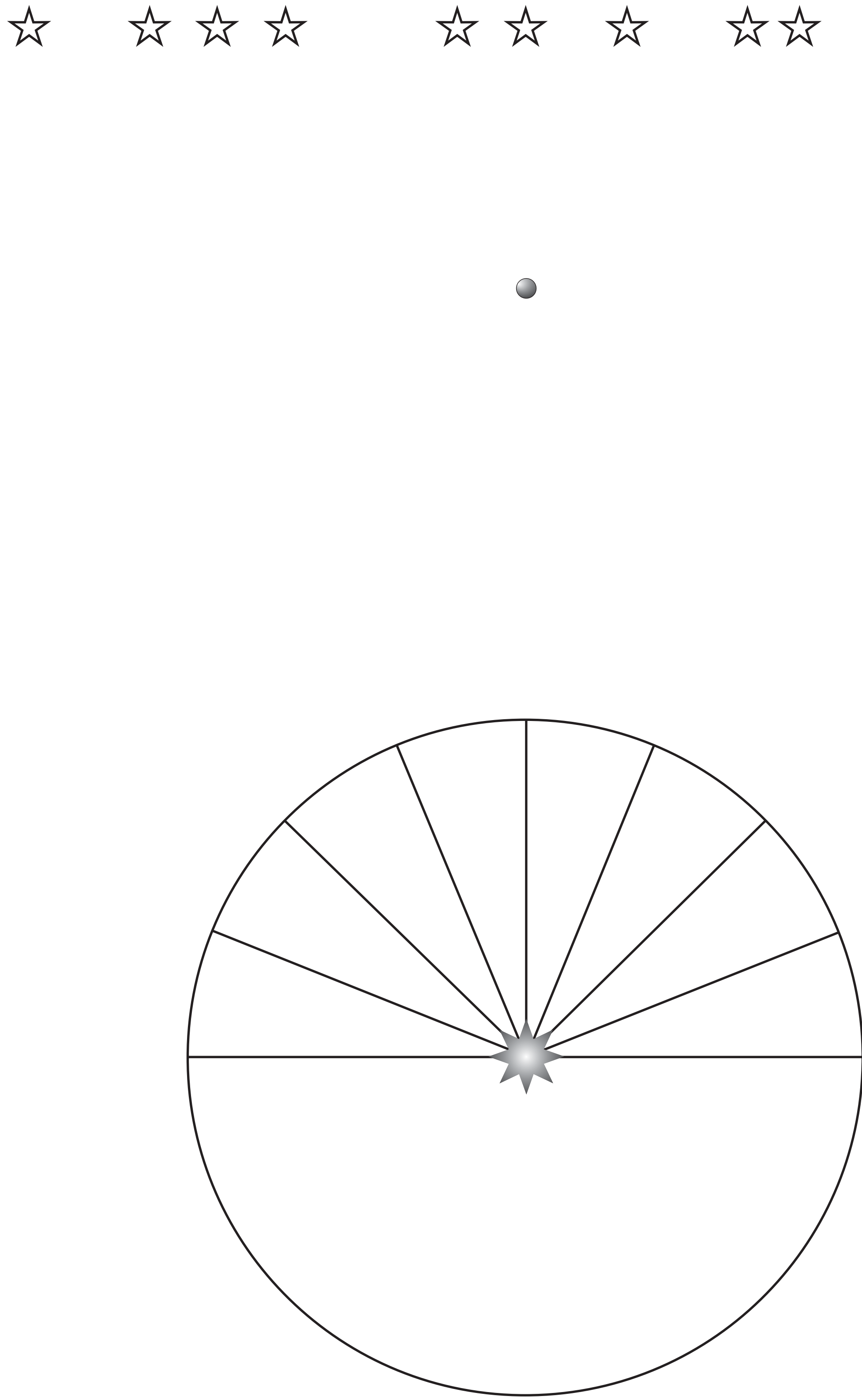
The teacher will describe the observing activities and how to use the charts.

List the date and the rise or set time for your selected star. Describe the weather if it prevented a time observation.

Compare the colors of Jupiter and Saturn to the colors of the brightest stars. Reddish stars (actually salmon-colored) have temperatures of 3000–4000 degrees Celsius and bluish stars have temperatures exceeding 10,000 degrees Celsius. Jupiter's naked-eye color matches the Sun's. What would you conclude the temperature of the Sun to be?

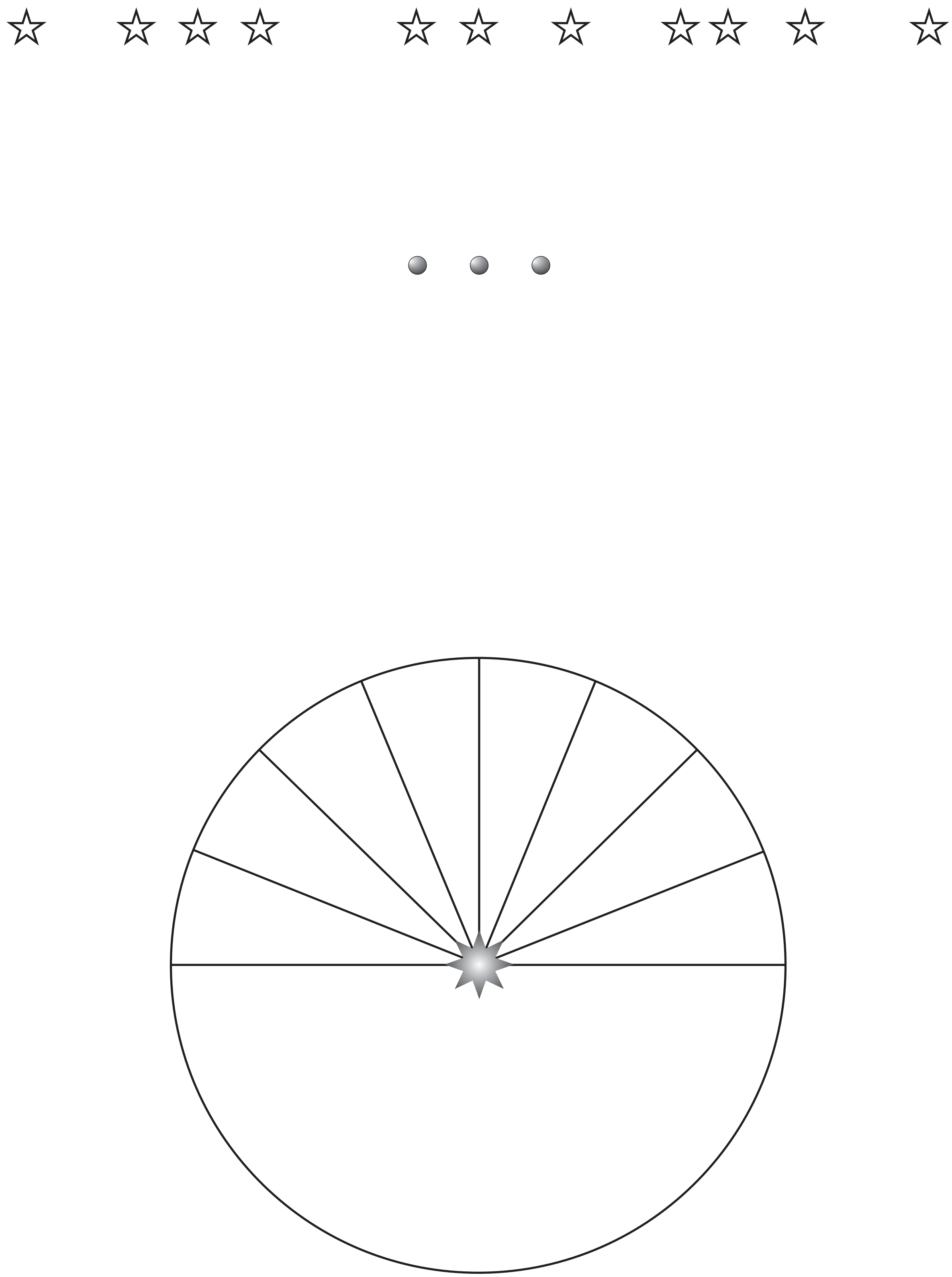
Sketch the positions of the moons relative to Jupiter. By making nightly drawings over a period of a few weeks it is possible to sort out which moons are which, based on how frequently they circle Jupiter and their maximum apparent distance from the planet. Imagine yourself as Galileo in 1610 seeing the moons for the first time. How far from the planet does each moon get? How fast does each go from side to side and back? Are there any color differences between them? Use a telescope and sketch Titan's motion around Saturn. How long does it take to make a revolution around Saturn?

Background Stars



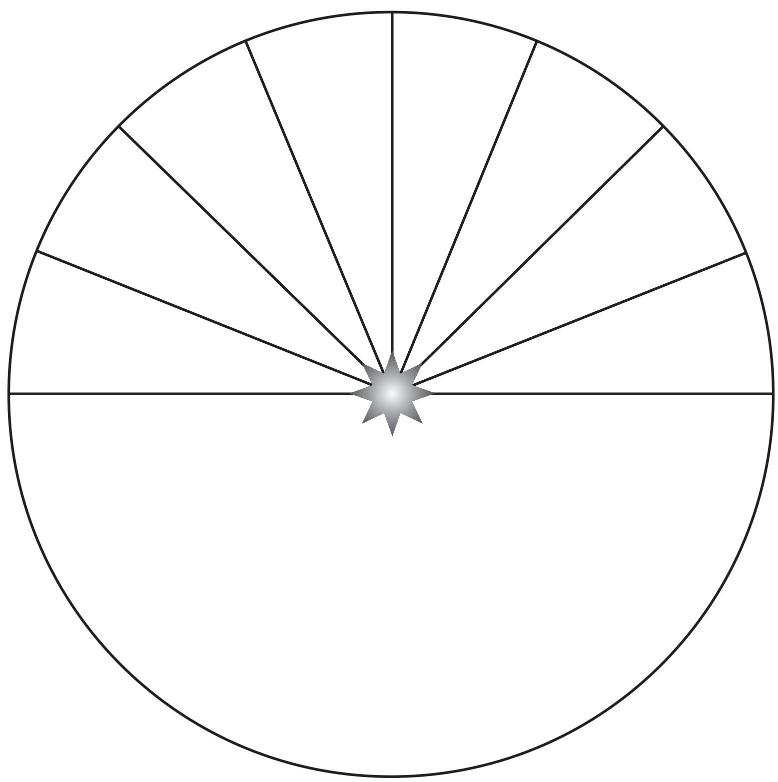
Planet Orbit Chart

Background Stars



Simulated-Motion Chart

Background Stars



Star-Rise Chart